ผลของแซนแทนกัมต่อการพัฒนาขนมครกแช่เยือกแข็งทดแทนด้วยแป้งข้าวกล้องสังข์หยด

EFFECT OF XANTHAN GUM IN THE DEVELOPMENT OF FROZEN KANOM KROK REPLACED WITH SANGYOD BROWN RICE FLOUR

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***Received:** February 18, 2019; **Revised:** April 19, 2019; **Accepted:** April 24, 2019*

บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อพัฒนาผลิตภัณฑ์ขนมครกแช่เยือกแข็งทดแทนแป้งข้าวกล้องสังข์หยด พบว่า ข้าวกล้องสังข์หยดมีค่า L* a* และ b* เท่ากับ 72.17±0.38, 6.50±0.11 และ 11.30±0.07 ตามลำดับ ความสามารถในการดูดซับน้ำและความสามารถในการละลายน้ำมีค่าเท่ากับ 2.68±0.04 และ 0.24±0.06 ตามลำดับ และเมื่อทำการทดแทนแป้งข้าวกล้องสังข์หยดที่ระดับร้อยละ 0 2 4 และ 6 ของน้ำหนักแป้งข้าวเจ้า พบว่า ส่วนหน้าและส่วนฐานขนมครกมีค่า L* ลดลง ส่วนค่า a* และ b* เพิ่มขึ้น ($p<0.05$) เมื่อระดับการทดแทนแป้งข้าวกล้องสังข์หยดเพิ่มขึ้น โดยขนมครกที่ทดแทนแป้งข้าวกล้องสังข์หยดที่ระดับร้อยละ 6 มีคะแนนความชอบด้านลักษณะปรากฏ สี กลิ่น กลิ่นรส เนื้อสัมผัส และความชอบโดยรวมมากที่สุด แล้วทำการศึกษาการปรับปรุงคุณภาพขนมครกแช่เยือกแข็งในระหว่างการเก็บรักษาแบบแช่เยือกแข็งโดยการเติมแซนแทนกัมที่ระดับร้อยละ 0 1 และ 2 ของน้ำหนักแป้งทั้งหมด พบว่า ค่า L* a* และ b* ของหน้าขนมครกหลังปรุงสุกที่เติมและไม่เติมแซนแทนกัมมีค่าไม่แตกต่างกัน ($p\geq0.05$) และมีแนวโน้มเพิ่มขึ้นเมื่อระยะเวลาในการเก็บรักษานานขึ้น ส่วนค่า L* a* และ b* ของส่วนฐานขนมครกที่เติมแซนแทนกัมมีค่ามากกว่าขนมครกที่ไม่เติมแซนแทนกัม และมีค่า L* เพิ่มขึ้นเล็กน้อยเมื่อระยะเวลาการแช่เยือกแข็งนานขึ้น นอกจากนี้พบว่า ความชื้นของขนมครกที่เติมแซนแทนกัมมีค่าคงที่ที่ระยะเวลาการเก็บรักษา 14 วัน และลดลงอย่างรวดเร็วที่ระยะเวลาการเก็บรักษา 21 วัน โดยขนมครกที่เติมแซนแทนกัมมีคะแนนความชอบในทุกคุณลักษณะมากกว่าขนมครกที่เติมแซนแทนกัม และคะแนนความชอบไม่มีความแตกต่างกันที่ทุกระดับการเติมแซนแทนกัม

คำสำคัญ: ขนมครก ขนมไทยแช่เยือกแข็ง แป้งข้าวสังข์หยด แซนแทนกัม

Abstract

The objective of this research was to develop the frozen Thai dessert “Kanom-krok” from rice flour replaced with Sangyod brown rice flour**.** The physical characteristic of Sangyod rice flour was determined. L*, a* and b* values of Sangyod rice flour were 72.17±0.38, 6.50±0.11 and 11.30±0.07, respectively. Water absorption and solubility index of Sangyod rice flour were 2.68±0.04 and 0.24±0.06, respectively. The characteristics of sample replaced with Sangyod rice flour at the level of 0, 2, 4 and 6 g/100 g of rice flour were investigated. The result indicated that L* (lightness) value of sample was significantly decreased ($p<0.05$) and a* and b* value were significantly increased ($p<0.05$) when increasing the Sangyod rice flour level. The sample replaced with 6% Sangyod rice flour showed the highest score in appearance, color, odor, flavor, texture and overall liking aspects. The suitable amount of xanthan gum to improve Kanom krok during frozen storage time was also investigated. Xanthan gum was added into the Kanom krok formula at the level of 0, 1 and 2 g/100 g of total flour. The L*, a* and b* values on the top of cooked Kanom krok with and without xanthan gum shown were not significantly different ($p\geq0.05$). Both samples were tended to increase when increasing frozen storage time. The L*, a* and b* values on the bottom of cooked Kanom krok with xanthan gum were higher than the sample without xanthan gum and L* value slightly increased with increasing frozen storage time. The water content of the Kanom krok threated with xanthan gum were constant throughout the 14 days frozen storage time and dramatically decreased on 21 days frozen storage time. In addition, the sample treated with xanthan gum showed the highest overall preference scores of samples comparing without xanthan gum. However, there were no significantly differences among the level of xanthan gum.

Keywords: Kanom krok, Frozen thai dessert, Sangyod rice flour, Xanthan gum

Introduction

Kanom Krok is a special coconut pudding that is unique in Thailand. It is often prepared and sold by the local vendors on the street-side. It is fragrant, sweet and the texture is also smooth due to the coconut milk. It can also be found in Bangladesh, Myanmar and Laos. In Indonesia, there is something which is similar to Kanom Krok called serabi. Kanom krok is made of rice flour, sugar, and coconut milk mixing to form two separate batters, one is salty and the other one is sweet, both of which are cooked in a heating mantle. After being cooked, the two half-circular pieces will be picked out from the mantle and formed into a circular shape. These sweet, salty, custardy bite–sized hotcakes are popularly served at breakfast time by push-cart vendors throughout Thailand. They can be served plain or with scallions, pumpkin, taro, corn and cilantro. Kanom krok is so delicious when eaten hot with a soft creamy center and extra crispy edges. However, it is well- known that it has a short shelf life and better to eat immediately after taken out from the mantle. Extending the shelf life of Kanom krok is a challenge as the demand for ready to eat products is high. Considering this need, freezing has been used widely. Ready-to-eat meals have been popularly consumed during the past decade due to their convenience. Many of the meals are composed of starch or flour as the main component. Such meals include noodles, breads, and desserts.

However, native starch or flour cannot be directly used in chilled and frozen food industry due to its high retrogradation and syneresis [1]. Freezing and frozen storage may cause the product changes considerably on qualities and textural properties. Several studies have shown the reports of retrogradation of starch in Thai dessert products that always occur when they are stored at low temperature or at fluctuated temperature condition [1-3]. To solve this problem, the bakery industry has recently appeared with the use of alternative flour mixes or hydrocolloids which influence on product structure, sensory attributes and storage stability in order to improve moisture retention, and to maintain overall product quality during storage [4-6].

Xanthan gum is used to improve the textural properties and moisture retention in cake batters and doughs, increase the volume and shelf life of cereal foods by limiting starch retrogradation and improve their eating quality [7]. Moreover, a stability, syneresis control, and consistent viscosity during freeze–thaw cycles and heating are achieved by adding xanthan gum to a variety of frozen products [8]. The beneficial effects of xanthan gum can be obtained even at very low levels of gum addition, typically 0.1–1.0% [7]. Moreover, the inclusion of dietary fiber into food matrix could improve the daily intake value, thereby decrease the risks of disease (colon cancer, type 2 diabetes and overweight ects). Therefore Sanyod brown rice (a nature color as dark red and violet), which has a high nutritional value of bran and embryo contain numerous nutritional be led to substitution into the formula. Also, the aim of this experimental work was to develop the nutritional enriched Sangyod brown rice flour frozen Thai dessert "Kanom-krok" and study the effect of Sangyod brown rice flour substitution. The effect of adding xanthan gum and frozen storage time on qualities of samples were also determined.

Objectives

This research was subject to determine the properties and develop frozen Kanom krok made from rice flour replacements with Sangyod brown rice flour. The physicochemical properties and sensory evaluation of Kanom krok were determined. The effect of xanthan gum and frozen storage time were also investigated.

Methods

1. Sangyod rice flour preparation

Sangyod brown rice from Patthalung, Thailand, was milled and sieved through 60 mesh and dried in a hot air oven at 60^{o}C until the moisture content was less than 10%. The other raw materials used were; rice flour, glutinous rice flour, coconut milk, sugar and salt, which were obtained from a local market in Muang Songkhla, Songkhla, Thailand.

2. Physicochemical properties of Sangyod brown rice flour

The color of Sangyod brown rice flour in the powder form was measured by using a CIE Hunter Lab and recorded by using CIE-L*, a* and b* uniform color space (CIE-Lab). Solubility and Water absorption of flour were analyzed [9].

3. Production and properties of Kanom krok

The bottom of Kanom krok was prepared by using ingredients according to table 1, which rice flour was replaced with Sangyod rice flour at the level of 0, 2, 4 and 6 g/100 g rice flour. The bottom consisting of rice flour, glutinous rice flour, coconut and hot water was mixed until it was smooth and then proofed for 20 minutes at room temperature (25°C). When the Kanom krok pan was hot, brush the surface indentations with vegetable oil before spooning the Kanom krok batter into each well for 1 table spoon. Before the batter sets, add a dab of the sweet coconut cream mixture on the top, to fill and sprinkle the center of each bottom with 1 tea spoon of the toppings, cover with a round lid and allow cooking for 15 minutes and remove gently with a rounded spoon as described in Figure 1.

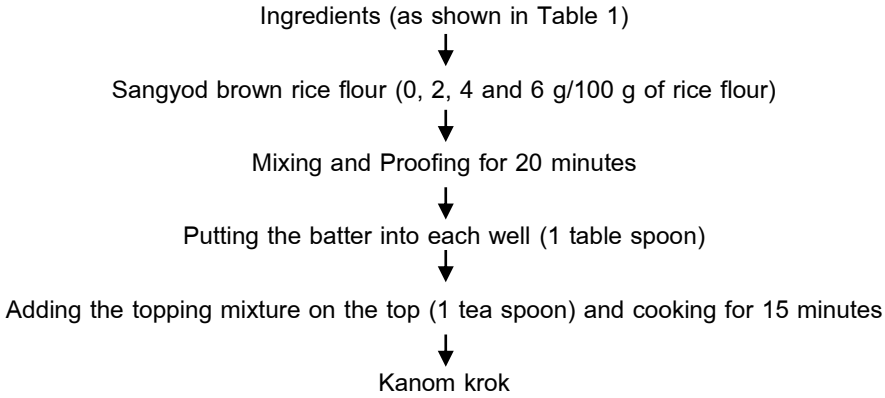

Figure 1. Kanom krok preparation.

Table 1 Ingredients of Kanom krok.

Ingredients	Content (g/100 g)	
	Bottom layer	Topping
Rice flour	85.84	-
Glutinous rice flour	14.08	-
Hot water	0.86	-
Coconut milk	0.64	0.64
Iodized salt	0.43	0.43
White sugar	0.43	0.43

The L*, a* and b* value of the top and bottom of Kanom krok was measured by using CIE-L*, a* and b* uniform color space (CIE-Lab). The moisture content was determined according to the method of AOAC [10]. The water activity (aw) was evaluated by using a water activity meter (Aqualab, USA).

Sensory evaluation was tested by 30 untrained panelists using a 9-point hedonic scale in aspects of appearance, color, flavor, texture and overall liking.

4. Effect of xanthan gum on characteristics of Kanom krok during frozen storage time

Kanom krok which shown the highest overall liking aspects was taken to study the effect of xanthan gum and characteristic of samples were determined. Xanthan gum was added into the Kanom krok formula at the level of 0, 1 and 2 g/100 g of total flour. Kanom krok was prepared as described in Figure 1. 10 pieces of Kanom krok were packed in polyethylene bag and then frozen in still air freezer at -18^{o}C. Then the samples were stored at -18^{o}C for 0, 7, 14 and 21 days. Frozen Kanom krok was cooked by microwave (800 w, 3 min) and taken to measure the L*, a* and b* value. The moisture content and sensory evaluation were also determined as mentioned in (3).

5. Statistical analysis

All samples were compared with a complete randomize design (CRD) and Randomized Completely Block Design, RCBD for sensory evaluation. Analysis of variance (ANOVA) was performed and means comparisons were carried out using Duncan's Multiple Range Test (DMRT).

Results

1. Physicochemical properties of Sangyod brown rice flour

L* (lightness), a* (redness) and b* (yellowness) value of Sangyod brown rice flour were 72.17±0.38, 6.50±0.11 and 11.30±0.07, respectively. This result shown the color of flour was light brown (Figure 2). Water absorption and water solubility of Sangyod brown rice flour were 2.78±0.04 and 0.26±0.06, respectively.

Figure 2. Sangyod brown rice flour.

2. The characteristic and sensory evaluation of Kanom krok

L* values of the bottom layer was significantly decreased ($p<0.05$) but a* and b* values of the bottom were significantly increased ($p<0.05$) when increasing Sangyod rice flour level (Figure 5). However, the color showing on the top was not different (Figure 3-4). Moisture content of cooked Kanom krok replaced with 2 g/100 g Sangyod rice flour was not different from Kanom krok without Sangyod rice flour (control). However, the moisture content increased when increasing Sangyod rice flour to 4 g/100 g (Table 3). Moreover, a_w was increased when replacing with Sangyod rice flour, all of Sangyod rice flour replacement level was not different ($p\geq0.05$).

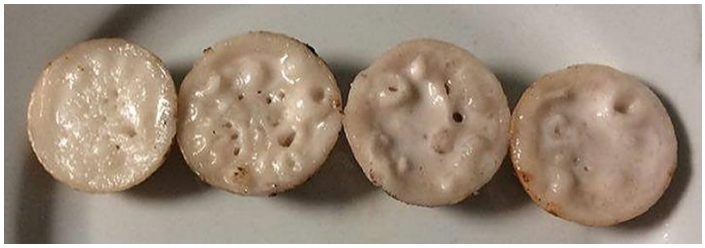

Figure 3. Kanom krok replaced with Sangyod rice flour at 0, 2, 4 and 6 g/100 g rice flour.

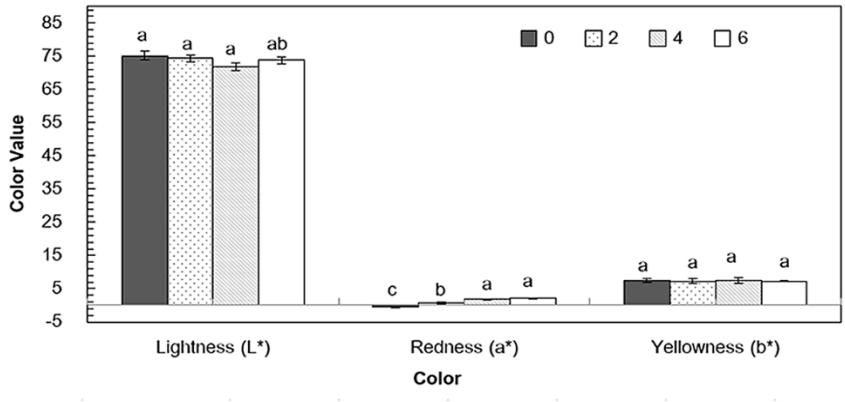

Figure 4. Color of cooked Kanom krok's top replaced with Sangyod rice flour at 0, 2, 4 and 6 g/100 g rice flour.

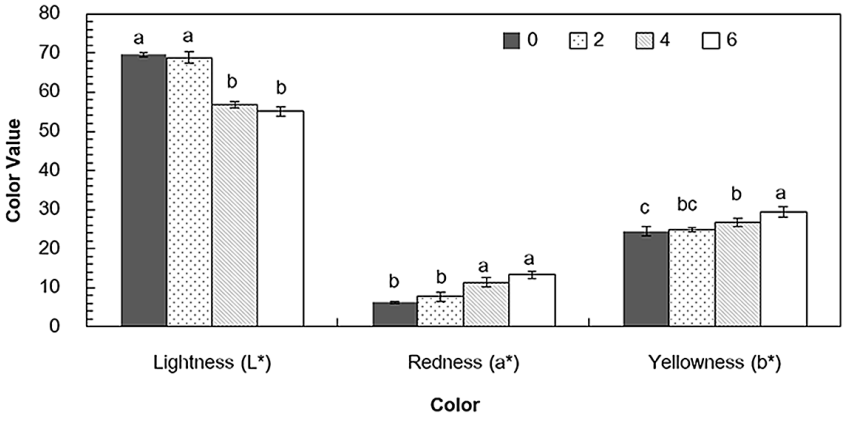

Figure 5. Color of cooked Kanom krok's bottom replaced with Sangyod rice flour at 0, 2, 4 and 6 g/100 g rice flour.

Table 3 Moisture content and water activity (a_w) of cooked Kanom krok replaced with Sangyod rice flour.

Sangyod rice flour (g/100 g)	Moisture content (%)	a_w (%)
0	48.13±0.15[b]	0.961±0.006[b]
2	47.13±2.35[b]	0.968±0.001[a]
4	52.37±1.30[a]	0.971±0.001[a]
6	52.03±1.46[a]	0.972±0.001[a]

Note. Each value is mean of triplicate ± S.D. and values within a column followed by the same letter are not significantly different ($p \geq 0.05$).

Sensory evaluation of cooked Kanom krok was tested by 30 panellists using a 9-point hedonic scale in aspects of flavor, texture and overall liking. The overall liking tended to increase when increasing Sangyod rice flour level (Table 4). However, appearance, color and odor score shown was not significantly different ($p \geq 0.05$). Kanom krok with 6 g/100 g Sangyod rice flour had the highest overall liking score but it was not significantly different ($p \geq 0.05$) when comparing with other replacement level. Then Kanom krok with 6 g/100 g Sangyod rice flour level was further taken to study the effect of xanthan gum on characteristics of Kanom krok during frozen storage time.

Table 4 Sensory evaluation of cooked Kanom krok replaced with Sangyod rice flour.

Sangyod rice flour (g/100 g)	Sensory attributes					
	Appearance	Color	Odor	Flavor	Texture	Over all liking
0	7.07±0.87[a]	7.23±1.04[a]	7.57±0.86[a]	6.80±1.03[b]	6.60±0.77[b]	6.97±0.76[b]
2	7.17±0.95[a]	7.33±0.88[a]	7.43±0.90[a]	7.07±1.08[ab]	7.13±0.86[a]	7.40±0.93[ab]
4	7.03±0.81[a]	7.13±0.90[a]	7.17±0.91[a]	7.13±0.97[ab]	7.20±0.92[a]	7.47±0.94[a]
6	7.23±0.68[a]	7.23±0.73[a]	7.43±1.01[a]	7.57±1.07[a]	7.23±1.01[a]	7.70±0.88[a]

Note. Each value is mean of triplicate ± S.D. and values within a column followed by the same letter are not significantly different ($p \geq 0.05$).

3. The characteristics of Kanom krok with xanthan gum during frozen storage time

The characteristics of Kanom krok with xanthan gum during frozen storage time 1, 7, 14 and 21 days were investigated (Figure 6-8). L*, a* and b* values on the top of cooked Kanom krok with and without xanthan gum shown were not significantly different ($p \geq 0.05$). However, the L*, a* and b* values of cooked Kanom krok rapidly increased during the first 7 days and remained constant during 14-21 days of storage. The L*, a* and b* values on the bottom of cooked Kanom krok with xanthan gum were higher than the sample without xanthan gum. Moreover, the moisture content of frozen Kanom krok without xanthan gum after thawing was less than the sample with xanthan gum (Figure 9). The moisture content

of frozen Kanom krok with and without xanthan gum decreased when increasing frozen storage time. However, the moisture content of Kanom krok with 2 g/100 g xanthan gum slightly decreased less than the sample with 1 g/100 g and without xanthan gum, respectively during frozen storage time.

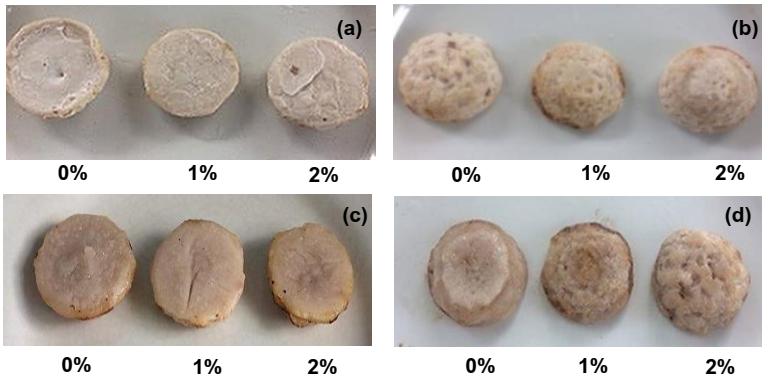

Figure 6. Frozen Kanom krok replaced with xanthan gum 0, 1 and 2 g/100 g; top (a) and bottom (b) of frozen Kanom krok, top (c) and bottom (d) of thawed Kanom krok during frozen storage time 21 days.

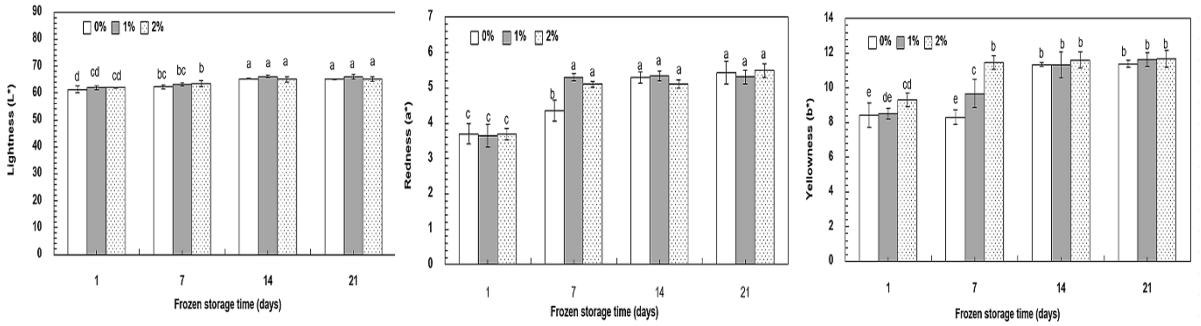

Figure 7. L*, a* and b* value on the top of frozen Kanom krok with xanthan gum 0, 1 and 2 g/100 g during frozen storage time.

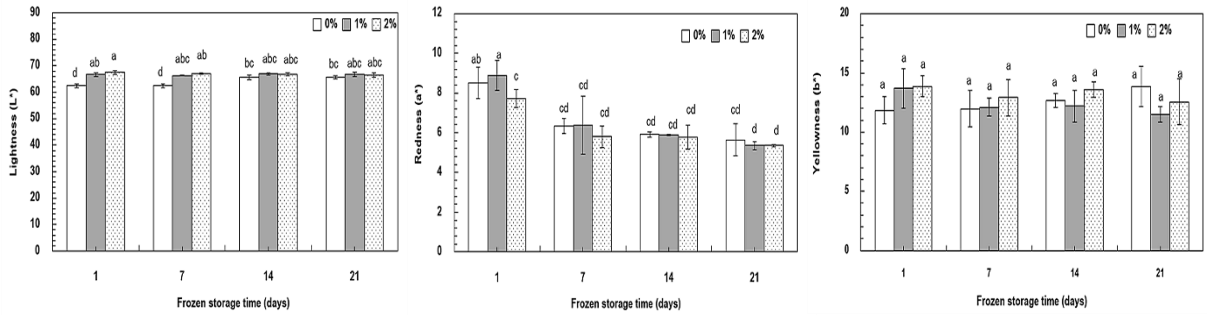

Figure 8. L*, a* and b* value on the bottom of Frozen Kanom krok with xanthan gum 0, 1 and 2% during frozen storage time.

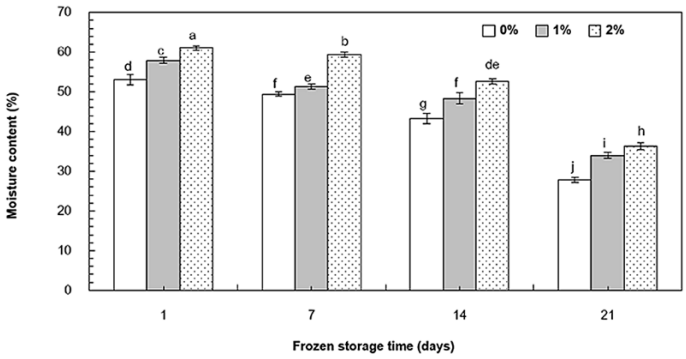

Figure 9. Moisture content of Kanom krok with xanthan gum 0, 1 and 2% during frozen storage time.

Sensory evaluation of cooked Kanom krok with and without xanthan gum were tested by 30 panellists using a 9-point hedonic scale in aspects of appearance, color, odor, flavor, texture and overall liking (Table 5). The result showed that all characteristics liking score of Kanom krok without xanthan gum tended to decrease when increasing frozen storage time. However, Kanom krok with various amounts of xanthan gum shown were not significantly different ($p \geq 0.05$) until 14 days of frozen storage time. Probably, due to the property of xanthan gum to bind freezable water and reduce water loss (syneresis) after thawing process. Moreover, the moisture content dramatically decreased when frozen storage time increasing to 21 days, due to slowly freezing process which led to forming ice crystals in frozen Kanom krok and possibly caused the damage of the gel structure of cooked Kanom krok when thawing.

Table 5 Sensory evaluation of Kanom krok with xanthan gum during frozen storage time.

Frozen storage time (days)	Xanthan gum (%)	Parameter					
		Appearance	Color	Odor	Flavor	Texture	Overall liking
1	0	7.33±0.48^{a}	7.10±0.71^{ab}	7.23±0.63^{a}	7.20±0.48^{ab}	6.83±0.99^{bc}	7.20±0.48^{b}
	1	7.30±0.47^{a}	7.00±0.69^{b}	7.10±0.88^{a}	7.37±0.85^{ab}	7.33±0.84^{a}	7.47±0.68^{ab}
	2	7.27±0.45^{a}	7.17±0.87^{ab}	7.20±0.89^{a}	7.40±1.00^{a}	7.43±0.86^{a}	7.53±0.82^{ab}
7	0	7.27±0.64^{a}	7.37±1.00^{ab}	7.53±0.78^{a}	7.23±0.94^{ab}	6.40±0.62^{d}	7.10±0.96^{b}
	1	7.20±0.85^{a}	7.23±0.82^{ab}	7.30±0.79^{a}	7.27±0.83^{ab}	7.07±0.94^{ab}	7.23±0.97^{b}
	2	7.07±0.98^{ab}	7.10±0.71^{ab}	7.13±0.78^{a}	7.17±0.83^{ab}	7.37±0.89^{a}	7.27±0.78^{ab}
14	0	6.77±0.43^{bc}	6.93±0.87^{b}	7.17±1.05^{a}	7.03±0.67^{ab}	6.40±0.50^{d}	7.17±0.65^{b}
	1	6.70±0.60^{cd}	7.47±0.82^{a}	7.30±0.92^{a}	7.30±0.92^{ab}	7.40±0.72^{a}	7.70±0.70^{a}
	2	6.70±0.47^{cd}	7.03±0.76^{ab}	7.40±0.77^{a}	7.20±0.92^{ab}	7.33±0.80^{a}	7.37±0.72^{ab}
21	0	6.37±0.49^{d}	6.47±0.78^{c}	7.07±0.69^{a}	6.90±0.76^{b}	6.30±0.63^{d}	6.57±0.68^{ab}
	1	6.63±0.49^{cd}	7.00±0.69^{b}	7.23±0.57^{a}	7.10±0.71^{ab}	7.00±0.64^{ab}	7.43±0.68^{ab}
	2	6.83±0.83^{bc}	7.03±0.56^{ab}	7.07±0.74^{a}	7.13±0.68^{ab}	7.10±0.80^{ab}	7.20±0.85^{b}

Note. Each value is mean of triplicate ± S.D. and values within a column followed by the same letter are not significantly different ($p \geq 0.05$).

Conclusions and Discussion

This research was subject to develop the frozen Kanom krok made from Sangyod brown rice flour. The suitable level of Sangyod brown rice flour was determined. The results showed that the Kanom krok replaced with 6 g/100 g of rice flour had the highest acceptability scores. However, the bottom of Kanom krok with higher level of Sangyod brown rice flour led to increase the darkness which affected by light brown characteristic of Sangyod brown rice flour. Nevertheless, there were no different among the top although the level of Sangyod brown rice flour increase. Because all sample were covered with sweet coconut cream on the top. Moreover, the moisture content increased when increasing Sangyod rice flour. The results indicated that the water absorption for the batter samples was affected by Sangyod brown rice flour incorporation and increased along with increasing the amount of Sangyod brown rice flour substitution. This phenomenon might be associated with higher fiber content of brown rice flour [11]. Nevertheless, the higher of Sangyod brown rice flour also led to increase in firmness. Probably due to the hydroxyl groups of Sangyod rice bran structure which allows more water interaction through hydrogen bonding [12-13] and it affected water absorbtion increased, led to being firm on Kanom krok. This result might effect on the acceptance of Kanom krok.

The Kanom krok replaced with Sangyod brown rice flour at the level of 6 g/100 g of rice flour was further taken to study the effect of xanthan gum on qualities of Kanom krok during frozen storage time. The results found that the adding of xanthan gum improved the moisture content and overall liking aspects of cooked Kanom krok during frozen storage time. Freezing and frozen storage time generated quality loss of Kanom krok. Without xanthan gum, Kanom krok had lower moisture content and acceptability score in appearance, color, texture and overall liking decreased when increasing frozen storage time. These results were expected because xanthan gum influences the starch structure, sensory attributes and storage stability. The hydroxyl groups in the hydrocolloids structure which allow more water interactions through hydrogen bonding will help to bind free water of Kanom krok and further to reduced water migration in the starch structure during frozen storage time [4, 12-14].

Furthermore, xanthan gum can improved moisture retention, and also maintain overall product quality during storage. This result indicated that deterioration in the quality of Kanom krok by ice crystals formation during freezing and recrystallization during frozen storage induce to the water to separate from the other components of the starch structure [15, 16]. Previous studied report the frozen storage time at -20 ˚C proceeds, the water content of samples was reduced gradually from 82-62% and gradually increased in retrogradation index when storage time prolonged [17]. However, the water decreasing it probably due to water evaporation at low freezing rate which take long freezing time. Another possible explanation for this is that during the slow freezing rate, cellular structures are damaged and therefore more water can migrate to the outside of the product during thawing [18]. Moreover, it more serves starch retrogradation occurred during slowly freezing process [1].

References

[1] Seetapa, N., Limparyoon, N., Gamonpilas, C., Methacanon, P., and Fuongfuchat, A. (2015). Effect of cryogenic freezing on textural properties and microstructure of rice flour/tapioca starch blend gel. *Journal of Food Engineering*. *151*, 51-59.

[2] Phimolsiripol, Y., Siripatrawan, U., Tulyathan, V., and Cleland, D. J. (2008). Effect of freezing and temperature fluctuations during frozen storage on frozen dough and bread quality. *Journal of Food Engineering*. *84*, 48-56.

[3] Mungmai, S. (2011). Effects of hydrocolloids on properties of frozen-Thai dessert (Kanomchan). *RAJABHAT AGRIC*. *10*(2), 32-42.

[4] Funami, T., Kataoka, Y., Omoto, T., Goto, Y., Asai, I., and Nishinari, K. (2005). Food hydrocolloids control the gelatinization and retrogradation behavior of starch. 2a. Functions of guar gums with different molecular weights on the gelatinization behavior of corn starch. *Food Hydrocolloids*. *19*, 15-24.

[5] Huang, M., Kennedy, J. F., Li, B., Xu, X., and Xie, B. J. (2007). Characters of rice starch gel modified by gellan, carrageenan, and glucomannan: A texture profile analysis study. *Carbohydrate Polymers*. *69*, 411-418.

[6] Kim, C., and Yoo, B. (2006). Rheological properties of rice starch–xanthan gum mixtures. *Journal of Food Engineering*. *75*, 120-128.

[7] Gimeno, E., Moraru, C. I., and Kokini, J. L. (2004). Effect of xanthan gum and CMC on the structure and texture of corn flour pellets expanded by microwave heating. *Cereal Chem*. *81*(1), 100-107.

[8] Sworn, G. (2000). *Xanthan Gum.* In G.O. Phillips, & P. A. Williams (Eds.), Handbook of hydrocolloids (pp. 103–115). Cambridge: Woodhead Publishing.

[9] Anderson, R. A., Conway, H. F., Pfeifer, V. F., and Griffin, E. L. (1969). Gelatinization of corn grits by roll and extrusion cooking. *Cereal Science Today*. *14*, 4-12.

[10] AOAC. (2000). *Official methods of analysis of the association of official analytical chemists*. 17th ed. Association of Official Analytical Chemists. Washington D. C.

[11] Khoshgozaran-Abras, S., Azizi, H.M., Bagheripoor-Fallah, N., and Khodamoradi, A. (2014). Effect of brown rice flour fortification on the quality of wheat-based dough and flat bread. *Journal of Food Science Technology*. *51*(10), 2821–2826.

[12] Guarda, A., Rosell, C. M., Benedito, C., and Galotto, M. J. (2004). Different hydrocolloids as bread improvers and anti-staling agents. *Food Hydrocolloids*. *18*, 241–247.

[13] Rosell, C. M., Rojas, J. A., and Benedito de Barber. (2001). Influence of hydrocolloids on dough rheology and bread quality. *Food Hydrocolloids*. *15*, 75-81.

[14] Sharadanant, R., and Khan K. (2003). Effect of hydrophilic gums on frozen dough. I. Dough quality. *Cereal Chemistry*. *80*, 764–772.

[15] Inoue, Y., and Bushuk W. (1992). Studies on frozen doughs. II. Flour quality requirements for bread production from frozen dough. *Cereal Chemistry. 69*, 423-428.

[16] Lee, M. H., Baek, M. H., Cha, D. S., and Lim ST. (2002). Freeze-Thaw stabilization of sweet potato starch gel by polysaccharide gums. *Food Hydrocolloids*. *16*, 345-352.

[17] Yang, Z., Han, X., Wu, H., Zhang, L., and Iqbal, J. M. (2017). Impact of emulsifiers addition on the retrogradation of rice gels during low-temperature storage. *Journal of Food Quality*. 1-7.

[18] Yu, S. F., Ma, Y., Tian, D., and Sun, D.W. (2010). *Combined effects of freezing and storage condition on the staling of cooked rice.* In XVIIth World Congress of the International Commission of Agricultural and Biosystems Engineering (CIGR). Quebec city, Canada.